(2) Automatic prevention of transmitting a DSC call on channel 70, except for a distress and safety call by DSC, when the channel is occupied by calls (Volume 4, Rec. ITU-R M.489-2);

c. Other aspects of DSC equipment (RR 54.2);

d. Narrowband direct printing (NBDP) message formats (Volume 4, Rec. ITU-R M.492-6) and error correction for distress, urgency, and safety messages (RR 32.43, 33.17, and 33.37, respectively);

e. Transmissions from satellite emergency position-indicating radio beacons (EPIRBs) operating in the bands 406-406.1 MHz and 1645.5-1646.5 MHz (RR Appendix 13 Part A5, Section I(c) and RR 34.1);

f. Transmissions from search and rescue radar transponders operating in the band 9200-9500 MHz (RR 5.474); and

g. Broadcasts on 518 (NAVTEX) and other broadcasts of maritime safety information using NBDP in the bands 4-27.5 MHz (RR 33.41).

Additionally, such stations when using DSC shall conform to the calling, acknowledgement, and operating procedures for DSC contained in the Radio Regulations (Article 32) and the relevant ITU-R recommendation(s).

2. 121.5/243 MHz EPIRBs:

EPIRBs operating at 121.5 MHz and/or 243 MHz shall conform to the requirements of Volume 4, Rec. ITU-R M.690.1 and Annex 10 to the Convention on International Civil Aviation, to the extent that each provision is applicable.

5.5 RADAR SPECTRUM ENGINEERING CRITERIA (RSEC)

5.5.1 General including RSEC-A

The wide application of radar for various functions makes large demands on the electromagnetic spectrum, and requires the application of effective frequency management measures for the equipment and systems involved. Criteria for certain equipment characteristics are specified herein to ensure an acceptable degree of electromagnetic compatibility among radar systems, and between such systems and those of other radio services sharing the frequency spectrum.

These criteria are concerned with promoting efficient use of the spectrum, and in specifying them there is no intent to require particular numerical values from the standpoint of the radar's mission. For example, characteristics such as power, sensitivity, pulse repetition rate, pulse duration, pulse rise and fall times, and the range of radio frequency emission are closely related to operational requirements. Accordingly, where limits for some of these characteristics are specified herein, the criteria have been chosen to avoid undue degradation of operational effectiveness. Moreover, the specification of these criteria is compatible with the policy of encouraging a free and unrestricted approach in further research looking toward more effective radars. Nevertheless, any proposals for new approaches and new system concepts involving radar must be reviewed from a frequency management viewpoint prior to development of new equipment.

Useful receiver techniques are available for reduction of the susceptibility of radars to low-duty-cycle pulse interference. The applicability of such devices as video integrators, correlators, PRF and pulse width discriminators varies with factors such as cost, availability, and their adaptability to specific equipment and environmental situations. While the mandatory incorporation of such devices is not specified herein, their application is recommended for low duty-cycle radars intended for operation in congested frequency bands and geographic areas.

All primary radars[9] shall be classified in one of five groups as shown in the following table and shall come under the criteria indicated for that group.

Applicability of RSEC [10, 11]

Radar Description	Applicable Criteria
Group A Non-pulsed radars of 40 watts or less rated average power; or Pulsed radars of 1 kW or less rated peak power; or Radars with an operating frequency above 40 GHz; or Man-portable[10] radars; or Man-transportable[11] radars; or Radionavigation radars in the band 9300-9500 MHz; as described above; or Expendable, non-recoverable radars on missiles	Criteria A Presently exempt from any RSEC
Group B Radars having a rated peak power of more than 1 kW but not more than 100 kW and operating between 2900 MHz and 40 GHz	Criteria B See 5.5.2
Group C All radars not included in Group A, B, D or E	Criteria C See 5.5.3
Group D All fixed radars in the 2700-2900 MHz band	Criteria D See 5.5.4
Group E Wind Profiler Radar (WPR) operating on 449 MHz	Criteria E See 5.5.5

For radars employing more than a single emitter, including phased array radars, variable PRF radars, radars whose modulation changes from pulse to pulse, and other special types of radars for which any of the following criteria cannot be directly applied, special methods may be required in establishing appropriate criteria. Pending adoption of technical criteria for such radars, values submitted for these parameters shall be accompanied by an explanation of their derivation.

The provisions of Section 5.5.2, Criteria B, are applicable to Class 1 spacebased radar systems[12] on a case-by-case basis. The provisions of Section 5.5.2 or Section 5.5.3 (i.e. Criteria B or C as appropriate) are applicable to Class 2 spacebased radar systems[13] and active spaceborne sensors[14] on a case-by-case basis. See Section 8.2.41 for further guidance concerning spacebased radiolocation and active sensor systems.

In the special case where government radionavigation radars operate in the shared government/ non-government band 9300-9500 MHz, an acceptable degree of electromagnetic compatibility is deemed to be that degree of compatibility associated with the radar equipment commercially available to the non-government community of users. The vast preponderance of the use of this band by non-government domestic and foreign ships and aircraft creates a situation where relatively inexpensive commercial equipment is available "off the shelf" and at the same time equipment improvements which might be incorporated unilaterally by small numbers of government stations would have little effect on the band as a whole. Accordingly, government radionavigation radars to be operated in this

9. Primary Radar: A radiodetermination system based on the comparison of reference signals with radio signals reflected from the position to be determined. (No. 1.101 of the ITU Radio Regulations, 2001 Edition.)
10. Man-portable: Items which are designed to be carried as a component part of individual, crew-served or team equipment in conjunction with assigned duties. These items are nominally less than 15 kilograms (32 pounds).
11. Man-transportable: items which are usually transported on wheeled, tracked or air vehicles but have integral provisions to allow periodic handling by one or more individuals for limited distances (i.e., 100-500 meters). These items are nominally less than 30 kilograms (65 pounds).
12. Spacebased Radiolocation System--Class 1: a radiolocation system in space the primary function of which is the detection and location of objects on or near the surface of the Earth.
13. Spacebased Radiolocation System--Class 2: a radiolocation system installed aboard a spacecraft for the purpose of determining the relative positions or velocities of one or more extravehicular objects.
14. Active Spaceborne Sensor--a measuring instrument in the earth exploration-satellite service, or in the space research service, by means of which physical measurements of various phenomena are obtained through transmission and reception of radio waves.

band having a rated peak power of 100 kW or less are placed in Group A with the understanding that government agencies would procure equipment that are acceptable for non-government use and that this exemption will be re-examined should the situation in this band change. Measurement procedures for RSEC may be found in Annex M, paragraph 2.1.2.A RSEC.

Waivers

Waiver of the requirements herein may be requested when supported by reasonable justification. When technical and engineering data are supplied in support of a request for waiver or in evaluating the performance of equipment, an explanation of the non-conforming parameters and measurement methods employed shall be furnished. Manufacturer's data may be used where deemed appropriate and adequate.

Pulse Characteristics and Emissions Mask

Figure 1 shows a radar pulse and where the pulse rise time (t$_r$) and pulse width (t) are calculated. Figure 2 shows the radar emission bandwidth and emission levels for Criteria B, C, and D.

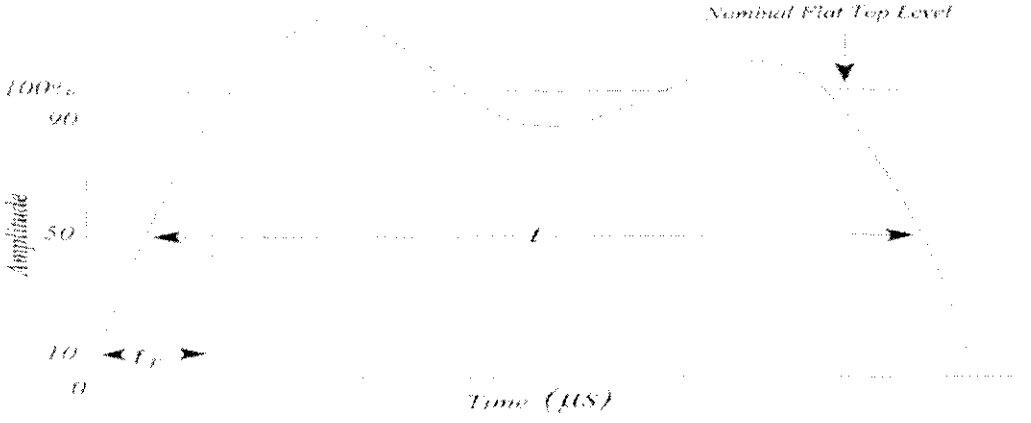
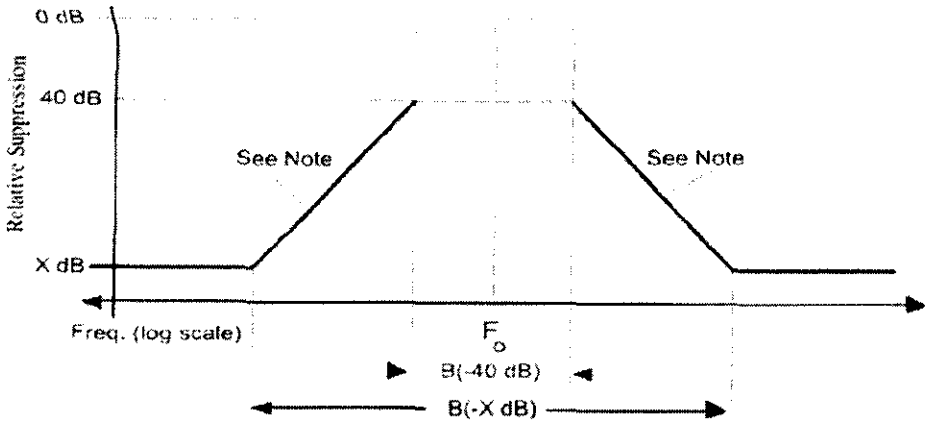


Figure 1. Determination of t and t_r



NOTE: The roll-off slope, S, from the -40 dB to -X dB points is at 20 dB per decade for Criteria B and C, and 40 to 80 dB per decade for Criteria D. The maximum emission spectrum level between the -40 dB and -X dB points for S dB per decade slope is described by the formula:

$$Suppression\ (dB) = -S \cdot \log\left|\frac{F - F_o}{\frac{1}{2}B(-40dB)}\right| - 40$$

$$Where:\ \frac{1}{2}B(-40dB) \le |F - F_o| \le \frac{1}{2}B(-XdB)$$

and: F is the frequency at which suppression is calculated

$$and:\ B(-XdB) = (10^{a})\ B(-40dB)$$

$$a = \frac{X-40}{S}$$

Figure 2. Radar Emission Bandwidth and Emission Levels

Symbols Used

B = emission bandwidth, in MHz.

B_c = bandwidth of the frequency deviation. (The total frequency shift during the pulse duration) in MHz.

B_d = bandwidth of the frequency deviation (peak difference between instantaneous frequency of the modulated wave and the carrier frequency)--(FM/CW radar systems).

B_s = maximum range in MHz over which the carrier frequency will be shifted for a frequency hopping radar.

d = pulse compression ratio = emitted pulse duration/compressed pulsed duration (at 50% amplitude points).

F_o = operating frequency in MHz. For non-FM pulse radars the peak of the power spectrum; for FM pulse radars the average of the lowest and highest carrier frequencies during the pulse.

N = total number of chips (subpulses) contained in the pulse. (N = 1 for non-FM and FM pulse radars.)

PG = processing gain (dB).

P_p = peak power (dBm).

PRR = pulse repetition rate in pulses per second.

P_t = maximum spectral power density –dBm/kHz.

t = emitted pulse duration in μ sec. at 50% amplitude (voltage) points. For coded pulses the pulse duration is the interval between 50% amplitude points of one chip (sub-pulse). The 100% amplitude is the nominal flat top level of the pulse (see Fig. 1).

t_r = emitted pulse rise time in μ sec. from the 10% to the 90% amplitude points on the leading edge. See Fig. 1. For coded pulses it is the rise time of a sub-pulse; if the sub-pulse rise time is not discernible, assume that it is 40% of the time to switch from one phase or sub-pulse to the next.

t_f = emitted pulse fall time in μ sec from the 90% to the 10% amplitude points on trailing edge. See Fig. 1 and endnote 15.

5.5.2 Criteria B

1. Effective Dates

Technical criteria for new radars became effective 1 October 1977 except as noted herein. (New radars are those for which development and subsequent procurement contracts are let after 1 October 1977.)

2. Applicability

These criteria are applicable to radars of Group B, "Radars having a rated peak power of more than 1 kW but not more than 100 kW and operating between 2900 MHz and 40 GHz."

3. Radar Emission Bandwidth

All radars procured prior to 1 January 1978 should be brought into compliance with the following standards when undergoing major overhaul.

The emission bandwidth for radars at the antenna input shall not exceed the following limits:

NOTE: There is also the "necessary bandwidth" parameter that is defined for radars. For the method of calculation, see Annex J.

3.1 For Non-FM pulse radars (including spread spectrum or coded pulse radars): [15]

$$B(-40dB) = \frac{7.6}{\sqrt{t_r t}} \quad \text{or} \quad \frac{64}{t}$$

whichever is less

3.2 For FM-pulse radars (intentional FM):[15]

$$B(-40dB) = \frac{7.6}{\sqrt{t_r t}} + 2\left(B_c + \frac{0.065}{t_r}\right)$$

For FM-pulse radars with pulse rise time, t_r, of less than 0.1 microsecond, an operational justification for the short rise time shall be provided.

3.3 For FM pulse radars (intentional FM) with frequency hopping: [15,16]

$$B(-40dB) = \frac{7.6}{\sqrt{t_r t}} + 2\left(B_c + \frac{0.065}{t_r}\right) + B_s$$

For FM pulse radars (intentional FM) with frequency hopping, but with pulse rise time, t_r, of less than 0.1 microsecond an operational justification for the short rise time shall be provided.

3.4 For frequency hopping radars using non-FM pulses (including spread spectrum or coded pulses):[15,16]

$$B(-40dB) = \frac{7.6}{\sqrt{t_r t}} + B_s$$

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15. If t_f is less that t_r, as defined in Part 5.5, t_f is to be used in place of t_r when performing the emission bandwidth calculations.
16. These formulas yield the total composite B(–40 dB) bandwidth of a frequency hopping radar as if all channels included within B_s were operating simultaneously. Individual channels have a B(-40 dB) radar emission bandwidth given by the equations in paragraph 3.1 or 3.2 of Sections 5.5.2, 5.5.3, and 5.5.4.

For this category of radars, an operational justification shall be provided if the pulse rise time, t_r, or fall time, t_f, is less than 0.01 microseconds.

3.5 For CW radars:

$$B(-40db) = 0.0003F_0 + 2B_d$$

3.6 For FM/CW radars:

$$B(-40db) = 0.0003F_0 + 2B_d$$

4. Emission Levels[17]

4.1 With the exception of CW and FM/CW radars, the radar emission level at the antenna input shall be no greater than the values obtainable from the curve in Figure 2. At the frequency $\pm B(-40dB)/2$ displaced from F_o, the level shall be at least 40 dB below the maximum value. Between the -40dB and -XdB frequencies the level shall be below the 20dB per decade (S=20) roll-off lines in Figure 2. At and beyond the frequencies $\pm$ B(-XdB)/2 from F_o, the level shall be at least the dB value below the maximum spectral power density given by:

$$X(dB) = 60dB \quad \text{or} \quad X(dB) = P_t + 30$$

whichever is the larger value

NOTE: P_t may be measured or may for the purpose of these criteria be calculated from the following:

$$P_t = P_p + 20\log(Nt) + 10\log(PRR) - PG - 90$$

where PG=0, for non-FM, non-encoded pulse radars
10log(d), for FM pulse radars
10log(N), for coded pulse radars

4.2 For CW and FM/CW radars, the levels of all emissions at the antenna input shall be no greater than the values obtainable from the curve in Figure 2. At the frequencies $\pm$ B(-40 dB)/2 displaced from F_o, the level shall be at least 40 dB below the maximum value. Between the -40 dB and -X dB frequencies, the level shall be below the 20 dB per decade (S=20) rolloff lines in Figure 2. At and beyond the frequencies $\pm$ B(X dB)/2 from F_o, the level shall be at least 60 dB below the maximum level of the signal contained within B(-40 dB). All levels are specified for a 1.0 kHz measurement bandwidth.

5. Antenna Pattern

No requirement is specified at present.

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17. For frequency hopping radars, the radar spectrum shall not intrude into adjacent spectrum regions on the high or low side of the allocation band, defined by B_s, more than would occur if the radar were fixed tuned at carrier frequencies equivalent to the end values of B_s and was complying with the constraints given by paragraphs 4.1 and 4.2 of Sections 5.5.2, 5.5.3, and 5.5.4.

6. Radar Tunability

Each radar shall be tunable in an essentially continuous manner either over the allocated bands for which it is designed to operate, or over a band which is 10% of the midband frequency. Crystal controlled radars conform to this requirement if operation at essentially any frequency across the band can be achieved with a crystal change.

7. Radar Receivers

The overall receiver selectivity characteristics shall be commensurate with or narrower than the transmitter bandwidth, as portrayed in Figure 2. Rejection of spurious responses, other than image responses, shall be 50 dB or better except where broadband front ends are required operationally. Receivers shall not exhibit any local oscillator radiation greater than –40 dBm at the receiver input terminals. The frequency stability shall be commensurate with, or better than, that of the associated transmitter.

8. Measurement Capability

See paragraph 2.1.2.B of Annex M.

5.5.3 Criteria C

1. Effective Dates

Technical criteria for new radars shall become effective 1 October 1977 except as noted herein. (New radars are those for which development and subsequent procurement contracts are let after 1 October 1977.)

2. Applicability

These criteria are applicable to radars of Group C, "all radars below 40 GHz not included in Group A, B or D".

3. Radar Emission Bandwidth

All radars procured prior to 1 January 1978 should be brought into compliance with the following standards when undergoing major overhaul.

The emission bandwidth for radars at the antenna input shall not exceed the following limits:

NOTE: There is also the "necessary bandwidth" parameter that is defined for radars. For the method of calculation, see Annex J.

3.1 For non-FM pulse radars (including spread spectrum or coded pulse radars):[15]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} \quad \text{or} \quad \frac{64}{t} \quad \text{whichever is less}$$

3.2 For FM-pulse radars (intentional FM):[15]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + 2\left(B_c + \frac{0.105}{t_r}\right)$$

For FM pulse radars with pulse rise time, t_r, or fall time, t_f, of less than 0.1 microsecond, an operational justification for the short rise time shall be provided.

3.3 For FM pulse radars (intentional FM) with frequency hopping: [15,16]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + 2\left(B_c + \frac{0.105}{t_r}\right) + B_s$$

For FM pulse radars (intentional FM) with frequency hopping, but with pulse rise time, t_r, of less than 0.1 microsecond, an operational justification for the short rise time shall be provided.

3.4 For frequency hopping radars using nonFM pulses (including spread spectrum or coded pulses):[15,16]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + B_s$$

For this category of radars, an operational justification shall be provided if the pulse rise time, t_r, is less than 0.01 microsecond.

3.5 For CW radars:

$$B(-40db) = 0.0003F_0$$

3.6 For FM/CW radars:

$$B(-40db) = 0.0003F_0 + 2B_d$$

4. Emission Levels [17]

4.1 With the exception of CW and FM/CW radars, the radar emission levels at the antenna input shall be no greater than the values obtainable from the curve in Figure 2. At the frequency ± B(-40 dB)/2 displaced from F_0, the level shall be at least 40 dB below the maximum value. Between the -40 dB and -X dB frequencies the level shall be below the 20 dB per decade (S=20) roll-off lines in Figure 2. At and beyond the frequencies ±B(-X dB)/2 from F_0, the level shall be at least the dB value below the maximum spectral power density given by:

$$X(dB) = 60dB \quad \text{or} \quad X(dB) = P_t + 30$$

whichever is the larger value

NOTE: P_t may be measured or may for the purpose of these criteria be calculated from the following:

$$P_t = P_p + 20\log(Nt) + 10\log(PRR) - (PG) - 90$$

where PG = 0, for non-FM, non-encoded pulse radars
10log(d), for FM pulse radars
10log(N), for coded pulse radars

4.2 For CW and FM/CW radars, the levels of all emissions at the antenna input shall be no greater than the values obtainable from the curve in Figure 2. At the frequencies ± B(-40 dB)/2 displaced from F_0, the level shall be at least 40 dB below the maximum value. All levels are specified for a 1.0 kHz measurement bandwidth. Between the -40 dB and -X dB frequencies, the level shall be below the 20 dB per decade (S=20) rolloff lines in Figure 2. At and beyond the frequencies ± B(X dB)/2 from F_0, the level shall be at least 60 dB below the maximum level of the signal contained within B(-40 dB).

5. Antenna Pattern

Since electromagnetic compatibility considerations involved phenomena which may occur at any angle, the allowable antenna patterns for many radars may be usefully described by "median gain" rel-

ative to an isotropic antenna18. Antennas operated by their rotation through 360° of the horizontal plane shall have a "median gain" of -10 dB or less, as measured on an antenna test range, in the principal horizontal plane. For other antennas, suppression of lobes other than the main antenna beam shall be provided to the following levels, referred to the main beam:

first three sidelobes: 17 dB;
all other lobes: 26 dB.

6. Radar Tunability

Each radar shall be tunable in an essentially continuous manner either over the allocated bands for which it is designed to operate, or over a band which is 10% of the midband frequency. Crystal controlled radars conform to this requirement if operation at essentially any frequency across the band can be achieved with a crystal change.

7. Radar Receivers

The overall receiver selectivity characteristics shall be commensurate with the transmitter bandwidth, as portrayed in Figure 2. Receivers shall be capable of switching bandwidth limits to appropriate values whenever the transmitter bandwidth is switched (pulse shape changed). Receiver image rejection shall be at least 50 dB; rejection of other spurious responses shall be at least 60 dB. Radar receivers shall not exhibit any local oscillator radiation greater than -40 dBm at the receiver input terminals. Frequency stability of receivers shall be commensurate with, or better than, that of the associated transmitters.

8. Measurement Capability

See paragraph 2.1.2.C of Annex M.

5.5.4 Criteria D

1. Effective Dates

Technical criteria for new fixed radars in the 2700-2900 MHz band shall become effective on 1 October 1982. (New radars are those for which the initial system procurement contract is let after 1 October 1982.)

2. Applicability

These criteria are applicable to fixed radars in the 2700-2900 MHz band. All radars subject to these criteria shall be designed and constructed to meet the basic minimum electromagnetic compatibility (EMC) requirements stated herein. In addition to the basic minimum EMC requirements, radar systems in the 2700-2900 MHz band which are intended to operate in close proximity to other equipment in the band or operate in areas specified in Annex D shall be designed and constructed to permit, without modification to the basic equipment, field incorporation of EMC enhancement provisions. These additional provisions will improve the electromagnetic compatibility of the radar thus improving the accommodation of the radar system in the band. These provisions are stated in Section 5.5.4, paragraph 8.

3. Radar Emission Bandwidth

The emission bandwidth for radars at the antenna input shall not exceed the following limits:

3.1 For non-FM pulse radars (including spread spectrum or coded pulse radars):[15]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}}$$

For non-FM pulse radars, a pulse rise time, t_r, or fall time, t_f,of less than 0.1t shall be justified:

3.2 For FM-pulse radars (intentional FM):[15]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + 2\left(B_c + \frac{0.105}{t_r}\right)$$

For FM pulse radars with pulse rise time, t_r, of less than 0.1 microsecond, a justification for the short rise time shall be provided.

3.3 For FM pulse radars (intentional FM) with frequency hopping: [15, 16]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + 2\left(B_c + \frac{0.105}{t_r}\right) + B_s$$

For FM pulse radars (intentional FM) with frequency hopping, but with pulse rise time, t_r, of less than 0.1 microsecond, an operational justification for the short rise time shall be provided.

3.4 For frequency hopping radars using non-FM pulses (including spread spectrum coded pulses):[15, 16]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + B_s$$

For this category of radars, an operational justification shall be provided if the pulse rise time, t_r, is less than 0.01 microsecond.

3.5 For CW radars:

$$B(-40db) = 0.0003F_0$$

3.6 For FM/CW radars:

$$B(-40db) = 0.0003F_0 + 2B_d$$

4. Emission Levels[17]

4.1 With the exception of CW and FM/CW radars, the radar emission levels at the antenna input shall be no greater than the values obtainable from the curve in Figure 2. At the frequencies $\pm$ B(–40 dB)/2 displaced from F_0 the level shall be at least 40 dB below the maximum value. Beyond the frequencies $\pm$B(–40 dB)/2 from F_0, the emission level(s), with the exception of harmonic frequencies, shall be below the 40 dB per decade (S=40) roll-off lines of Figure 2 down to a –X dB level that is 80 dB below the maximum spectral power density. All harmonic frequencies shall be at a level that is at least 60 dB below the maximum spectral power density.

4.2 For CW and FM/CW radars, the levels of all emissions at the antenna input shall be no greater than the values obtainable from the curve in Figure 2. At the frequencies $\pm$ B(–40 dB)/2 displaced from F_0, the level shall be at least 40 dB below the maximum value. Between the –40 dB and –X dB frequencies, the level shall be below the 40 dB per decade (S=40) rolloff lines in Figure 2. At and beyond the frequencies B(-X dB)/2 from F_0, the level shall be at least 80 dB below the maximum level of the signal contained with B(–40 dB). All levels are specified for a 1.0 kHz measurement bandwidth.

5. Antenna Pattern

Since electromagnetic compatibility considerations involved phenomena which may occur at any angle, the allowable antenna patterns for many radars may be usefully described by "median gain" relative to an isotropic antenna.[18] Antennas operated by their rotation through 360 degrees of the horizontal plane shall have a "median gain" of -10 dB or less, as measured on an antenna test range, in the principal horizontal plane. For other antennas, suppression of lobes other than the main antenna beam shall be provided to the following levels, referred to the main beam:

first three sidelobes--17 dB;
all other lobes--26 dB.

6. Radar Tunability

Radar systems shall be tunable over the entire 2700-2900 MHz band.

7. Radar Receiver

The overall receiver selectivity characteristics shall be commensurate with the transmitter bandwidth, as portrayed in Figure 2. Receivers shall be capable of switching bandwidth limits to appropriate values whenever the transmitter bandwidth is switched (pulse shape changed). Receiver image rejection shall be at least 50 dB; rejection of other spurious responses shall be at least 60 dB. Radar receivers shall not exhibit any local oscillator radiation greater than -40 dBm at the antenna input terminals. Frequency stability of receivers shall be commensurate with, or better than, that of the associated transmitters.

8. Additional EMC Provisions

To improve the accommodation of radar systems in the 2700-2900 MHz band which operate in close proximity to other equipment in the band or operate in areas specified in Annex D, the radar shall be designed and constructed to permit, without modification to the basic equipment, field incorporation of system EMC provisions. These provisions include the requirement to meet specifications in accordance with paragraphs a. and b. below and the recommendation to meet guidelines in accordance with paragraph c. below.

a. Emission Levels

The radar emission levels at the antenna input shall be no greater than the values obtainable from the curves in Figure 2. At the frequency $\pm$ B(-40 dB)/2 displaced from F_o, the level shall be at least 40 dB below the maximum value. Beyond the frequencies $\pm$B(-40 dB)/2 from F_o, the equipment shall have the capability to achieve up to 80 dB per decade (S=80) roll-off lines of Figure 2. The emission levels, with the exception of harmonic frequencies, shall be below the appropriate dB per decade roll-off lines of Figure 2 down to a -X dB level that is 80 dB below the maximum spectral power density. All harmonic frequencies shall be at a level that is at least 60 dB below the maximum spectral power density.

b. Radar System PRF

The radar system shall be designed to operate with an adjustable pulse repetition frequency (s), PRF (s), with a nominal difference of $\pm$ 1% (minimum). This will permit the selection of PRF's to allow certain types of receiver interference suppression circuitry to be effective.

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18. Median gain is defined as that level over an angular region at which the probability is 50% that the observed or measured gain at any position of the antenna will be less than or equal to that level.

c. Receiver Interference Suppression Circuitry

Radar systems in this band should have provisions incorporated into the system to suppress pulsed interference. The following information is intended for use as an aid in the design and development of receiver signal processing circuitry or software to suppress asynchronous pulsed interference. *A description of the parametric range of the expected environmental signal characteristics at the* receiver IF output is:

Peak Interference-to-Noise Ratio: $\leq$ 50 dB
Pulse width: 0.5 to 4.0 μsec
PRF: 100 to 2000 pps

8. Measurement Capability

See paragraph 2.1.2.C of Annex M.

5.5.5 Criteria E

1. Effective Dates

Technical criteria for new wind profiler radars (WPR) operating on 449 MHz shall become effective on 1 January 1994. (New WPRs are those for which the initial systems procurement contract is let after 1 January 1994.)

2. Applicability

These criteria are applicable to WPR's operating on 449 MHz.

3. Emission Bandwidth

The emission bandwidth for WPR's at the antenna input shall not exceed the following limits:

3.1 For non-FM pulse radars (including coded pulse radars): [15]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} \quad \text{or} \quad \frac{64}{t}$$

whichever is less.

3.2 For FM-pulse radars (intentional FM): [15]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + 2\left(B_c + \frac{0.105}{t_r}\right)$$

3.3 For wind profiler radars, an operational justification shall be provided if the pulse rise time, t_r, is less than 0.01 microsecond.

3.4 For CW radars

$$B(-40db) = 0.0003F_0$$

3.5 For FM/CW radars

$$B(-40db) = 0.0003F_0 + 2B_d$$

4. Emission Levels [17]

WPR emission levels at the antenna input shall be no greater than the values obtainable from the curve in Figure 3. At the Frequencies ± B(-40 dB)/2 displaced from F_0, the level shall be at least 40 dB below the maximum value. Between the -40 dB and -X dB frequencies, the level shall be below the 40 dB per decade (S=40) roll-off lines in Figure 3. At and beyond the frequencies ± B(-X dB)/2 from F_0, the level shall be at least the dB value below the maximum spectral power density given by:

$$X(dB) = 60dB \quad \text{or} \quad X(dB) = P_t + 30$$

whichever is the greater attenuation

All harmonic frequencies shall be at a level that is at least 60 dB below the maximum spectral power density.

NOTE: P_t may be measured or may for the purpose of these criteria be calculated from the following:

$$P_t = P_p + 20\log(Nt) + 10\log(PRR) - PG - 90$$

5. EIRP

The EIRP[a] of any WPR operating at 449 MHz shall not exceed the following values:

		Median	Maximum
for	elevation angle > 70 deg[b]		110 dBm
for	60< elevation angle ≤ 70 deg	83 dBm	95 dBm
for	45< elevation angle ≤ 60 deg	78 dBm	90 dBm
for	5< elevation angle ≤ 45 deg	73 dBm	85 dBm
for	elevation angle ≤ 5 deg	58 dBm	70 dBm

a. EIRP is the sum of two quantities: peak transmitter power in dBm and antenna gain in dBi. The column labeled Median is based on median antenna gain and the column labeled Maximum is based on maximum antenna gain.
b. The center of the antenna main beam generated at any time shall be limited to elevation angles greater than 70 degrees.

6. WPR Receiver

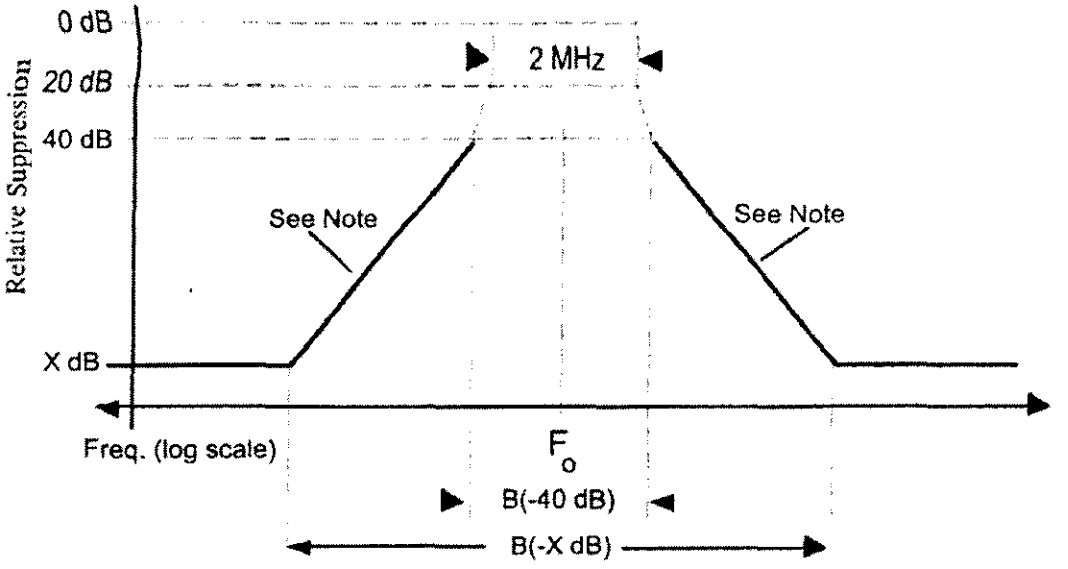
The -3 dB receiver bandwidth should be commensurate with the authorized emission bandwidth plus twice the transmitter frequency tolerance of 10 ppm (as specified in Section 5.2.1). The -60 dB receiver bandwidth shall be commensurate with the -60 dB emission bandwidth. Receivers shall be capable of switching bandwidth limits to appropriate values whenever the transmitter bandwidth is switched (pulse shape changed). Receiver IF image frequency rejection shall be at least 50 dB. Rejection of other spurious responses shall be at least 60 dB. WPR receivers shall not exhibit any local oscillator radiation greater than -40 dBm at the antenna input terminals.

7. EMC Provision

WPR's shall have the capacity to tolerate incoherent pulsed interference of duty cycles less than 1.5 percent such that peak interfering signal levels 30 dB greater than WPR receiver noise level at the IF output will not degrade WPR performance.

8. Measurement Capability

See paragraph 2.1.2.D of Annex M.



Note: The roll-off slope, S, from the -40 dB to -X dB points is at 40 dB per decade for Criteria E. The -20 dB bandwidth is limited to 2 MHz for Wind Profiler radars operating at 449 MHz. The maximum emission spectrum level between the -40 dB and -X dB points for S dB per decade slope is described by the formula:

$$Suppression\ (dB) = -S * \log\left|\frac{F - F_o}{\frac{1}{2}B(-40dB)}\right| - 40$$

$$Where:\ \frac{1}{2}B(-40dB) \le \left|F - F_o\right| \le \frac{1}{2}B(-XdB)$$

and: F is the frequency at which suppression is calculated

$$and:\ B(-XdB) = (10^a)\ B(-40dB)$$

$$a = \frac{X-40}{S}$$

Figure 3. Radar Emission Bandwidth and Emission Levels for Wind Profiler Radars at 449 MHz (Criteria E)

5.6 SPACE SERVICES

5.6.1 General

These requirements are applicable to U.S. Government space systems including associated earth terminals and space stations operating in portions of the spectrum allocated to the space services above 470 MHz. They do not apply to transmissions from radars on the ground or aboard spacecraft. Standards for radars aboard spacecraft are contained in Part 5.5. Standards for earth and space stations operating in bands below 470 MHz are contained in Part 5.2.

For planning and evaluation purposes this standard cannot be used alone. Modulation type, emission spectrum, power output, frequency tolerance, and maximum expected Doppler shift should be considered and provided in accordance with Chapter 10 of this Manual.

The requirements of this standard do not apply to deep space spacecraft transmitters while operating at distances greater than 2,000,000 km from Earth, in those frequency bands allocated to space research (space-to-earth) (Deep Space Only). This exemption of deep space spacecraft transmitters from unwanted emissions standards will be reviewed every 5 years, beginning in the year 2005. Such a review will take account of radio astronomy requirements (see RR **22.22-22.25**), as soon as radio astronomy activities on the Shielded Zone of the Moon, or in Deep Space get under way.

5.6.2 Unwanted Emission Mask

For frequencies offset from the assigned frequency less than the 50% of the necessary bandwidth (B_n), no attenuation is required. At a frequency offset equal to 50% of the necessary bandwidth, an attenuation of at least 8 dB is required. Frequencies offset more than 50% of the necessary bandwidth should be attenuated by the following mask:

$$40 \cdot \log\left(\frac{2 \cdot |f_d|}{B_n}\right) + 8 \qquad \text{dBsd}$$

where f_d is the frequency displaced from the center of the emission bandwidth.

- Annex J gives procedures for determining B_n.
- dBsd is dB attenuation in a 4 kHz bandwidth, relative to the maximum power in any 4 kHz bandwidth within the necessary bandwidth (0dBsd). Above 15 GHz, a 1 MHz bandwidth may be used.
- Attenuation in this sense refers to the reduction in level relative to the reference, 0 dBsd, unless otherwise specified.
- The unwanted emission mask rolls off at 40 dB per decade to a maximum attenuation of 60 dBsd, at which point it continues on both sides of the carrier for all frequencies beyond this point. See Figure 5.6.1. Annex M gives measurement requirements.
- For any narrowband or single frequency unwanted emission which is not spread by the modulation process, the required attenuation shall be at least 60 dBc, where dBc is attenuation below the mean transmit power, rather than the dBsd value determined above.

5.6.3 Multi-carrier Emissions and Multi-transponder Satellites

Multi-carrier transmitters/transponders are those where multiple carriers may be transmitted simultaneously from a final amplifier or an active antenna. For systems with multiple carriers, the limit on unwanted emissions should start at the edges of the total assigned bandwidth. For satellite systems, the necessary bandwidth used in the masks in 5.6.2 should be taken to be the lesser of 3 dB transponder bandwidth or the total assigned bandwidth. This bandwidth applies even when some of the carriers are not transmitted continuously, or when some carriers change in frequency. More information on unwanted emission masks for multi-carrier and multi-transponder systems can be found in ITU-R Recommendation SM.1541 and Appendix **3** to the ITU-R Radio Regulations.

5.6.4 Unwanted Emissions From One Transponder Falling Within The Frequency Band of Another Transponder On The Same Satellite

A single satellite operating with more than one transponder in the same service area may have unwanted emissions from one transponder falling on a frequency at which a second companion transponder is transmitting. The limits should not be applied to those unwanted emissions of a satellite that fall within the necessary emission bandwidth of another transponder, on the same satellite, into the same service area.

5.6.5 Narrow Band Emissions

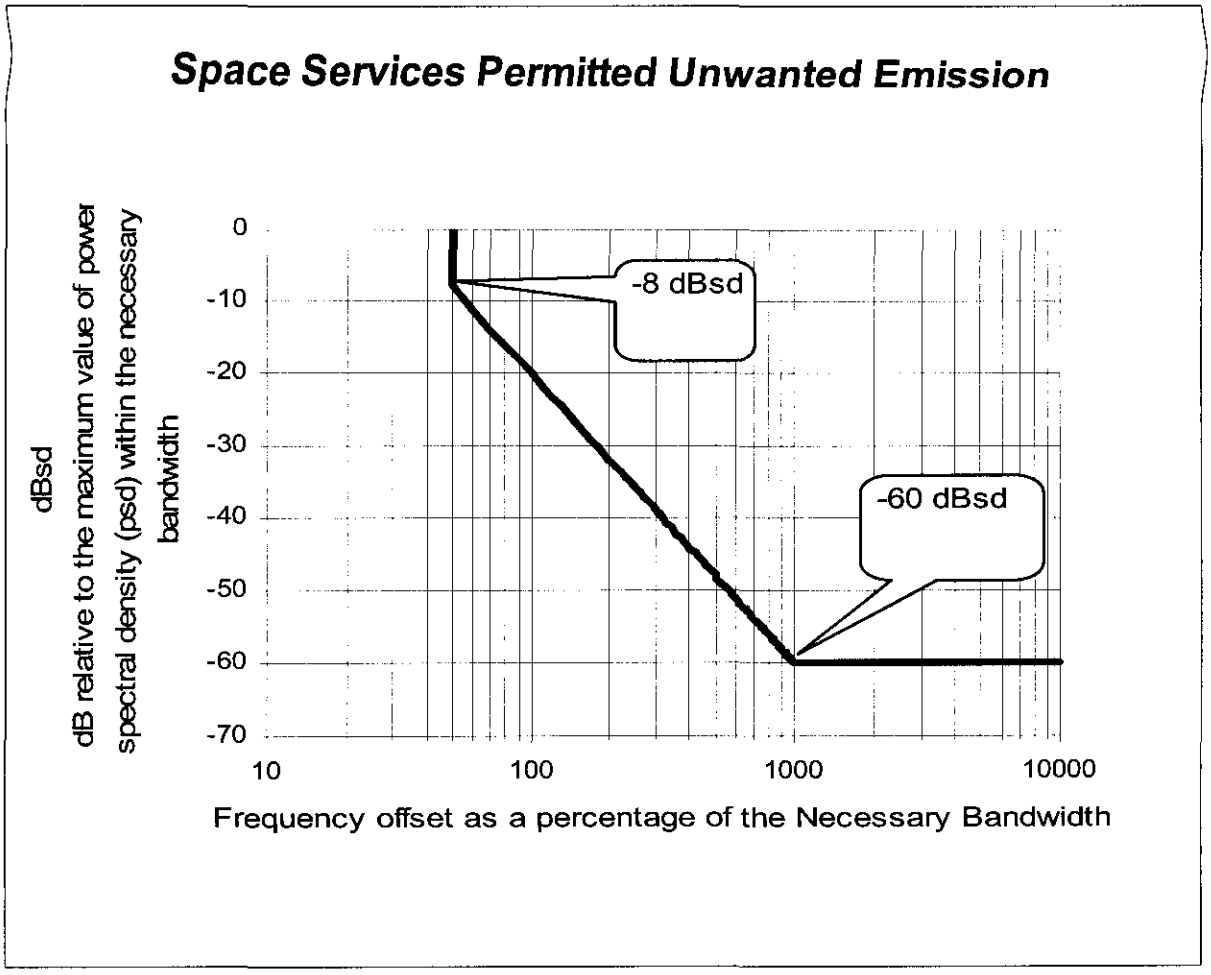
In the case of very narrow-band emissions where the necessary bandwidth is less than the minimum bandwidth (B_L) given in Table 5.6.1, B_L shall be used in place of B_n in Section 5.6.2 above. Examples include beacons, pilots and other unmodulated carriers.

Table 5.6.1 Minimum Bandwidth

Operating Frequency Range (fc)	Minimum Bandwidth (B_L)
470 MHz < fc < 1 GHz	25 kHz
1 GHz < fc < 10 GHz	100 kHz
10 GHz < fc < 15 GHz	300 kHz
15 GHz < fc < 26 GHz	500 kHz
fc > 26 GHz	1 MHz

In Table 5.6.1, f_c is the center frequency of the emission. If the assigned frequency band of the emissions extends across two frequency ranges, then the values corresponding to the higher frequency range may be used for the whole assignment.

Figure 5.6.1 Maximum Unwanted Emission Levels For Space Services



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